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EXPERIMENTAL INVESTIGATION OF SPRING BACK AND WRINKLING PHENOMENA IN SQUARE PIPES DURING BENDING

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ABSTRACT

Bending operation is one of the crucial steps in producing a variety of industrial products. The objective of this work is to design and fabricate a pipe bending die for making square shaped pipes. Design of the die is done in such a way that it can replace the circular pipe bending die in the metal forming lab of CBIT. This increases the utility of the machine and helps to calculate the bending load, spring back and wrinkling effect for a given size and thickness of square pipe. In this work, an attempt is made to investigate the effect of bend angle on spring back by varying the thickness of square pipe. Also, an effort is made to reduce the wrinkling effect occurring in square pipes during bending process. The studies reveal that spring back increases with increase in bend angle and with increase in pipe thickness spring back decreases.

KEYWORDS: Pipe Bending, Spring Back, Bending Die & Square Pipe

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1. INTRODUCTION TO BENDING PROCESS

Tube bending process is a metal forming process, in which, a tube is bent into required radius known as bend radius. Tube bending process has wide range of applications in the field of automobiles, aircrafts and structural constructions. They are also widely used in furniture. The total load in bending process consists of frictional forces and the ideal bending load. The tube that is to be bent is fixed by a vice clamp comprising of two pressure dies. The bending process in the machine take place by a hydraulically assisted rotary table, which pushes the fixed tube into fixed die by rotary action.

1.1. Types of Tube Bending Processes

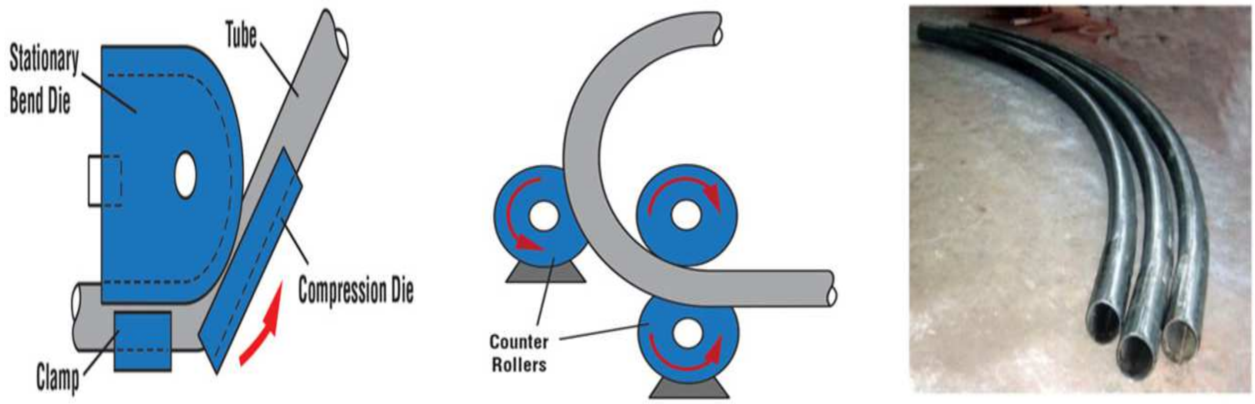
Bending process involves the change in shape of the tube without any additional material being added. Different bending machines are used to get different types of bends. The various types of bending operations are discussed below.

1.1.1. U- Bending

In this type of bending process, the bending is done up to 180 degrees. Figure 1(a) shows the U-bending process.

1.1.2. Circular Bending

The process in which, a pipe of any cross section is bent to form a complete circle consisting of three or more roller dies is called as circular bending. The applications of products obtained from this process are wheels, rims etc. Figure 1(b) shows the circular bending process.



(a) **U- Bending Process** **(b)** **Circular Bending** **(c)** **Arc Bending Process**

Figure 1: Various types of Bending Operations.

1.1.3. Arc Bending

In this process, the pipes are bent to form an arc. The main applications of this are ceilings, and curved beams which are mainly used in construction of structures. Figure 1(c) shows the arc bending process.

1.2. Applications of Square Pipes

Tube bending processes are used in many industries, which are used for different purposes like automobile chassis. Throttling pipes, structures and furniture. Some parts made out of square pipe bends are tables, ladders motor cycle big frames, electric Car’s main frames etc. Figure 2(a) and 2(b) shows various applications of square pipes.

1.3. Description of Bending Machine

The bending machine consists of robust metallic structure. It is mounted on a horizontal floor with rigid supports. Figure 3 shows hydraulic pipe bending machine used in the present work. The specifications of bending machine being used are given in table 1. The bending machine consists of tube bending die, clamping vice, pair of pressure dies, a circular scale, a rotary table, support bar and a control lever.

(a) **Table** **(b)** **Ladder**

Figure 2: Applications of Square Tube Bends.

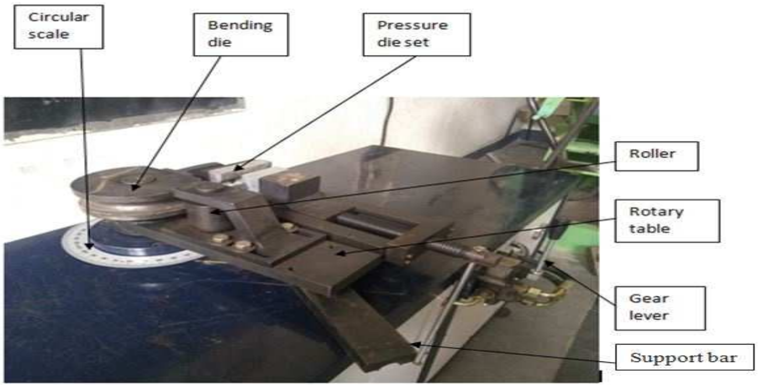


Figure 3: Tube Bending Machine used to carry out this Work.

1.3.1. Function of Bending Die

Bending die is a form tool, which is used to bend a tube to specific radius. This radius is termed as bending radius and is fixed for a die. It consists of a slot, made across its periphery to accommodate the bent tube, and it also consists of a slot made at the Centre to fix the position of the die. Figure 4(a) shows solid model of bending die.

1.3.2. Function of Pressure Die

The pressure dies enable to firmly fix the tube, so that there will be no sliding of the tube when the rotary table pushes the tube into the bending dies. Figure 4(b) shows the solid model of pressure die.

1.3.3. Role of Support Bar

Support bar has a slot made in it, to accommodate the tube during bending process. It is arranged between roller and pipe in a firm manner such that, it rolls along the length of the pipe during bending process. Figure 4(c) shows solid model of support bar.

Table 1: Specifications of Hydraulic Bending Machine

Model no	GEC 150
Bending speed	9 RPM
Tube feeding	Manual
Bending degree	0-360
Higher radius	200-2000
Base dimension	600x450x1400
Roller diameter	127mm
Power	3 H.P
Weight	450 kg

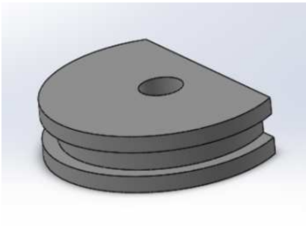


Figure 4 (a) Tube Bending Die.

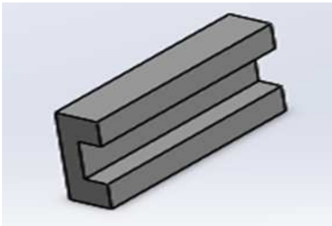


Figure 4 (b) Pressure Die.

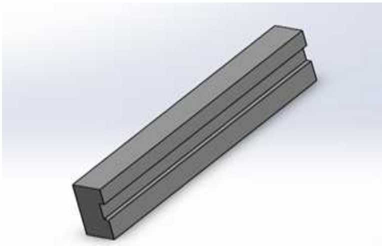


Figure 4(c) Support Bar.

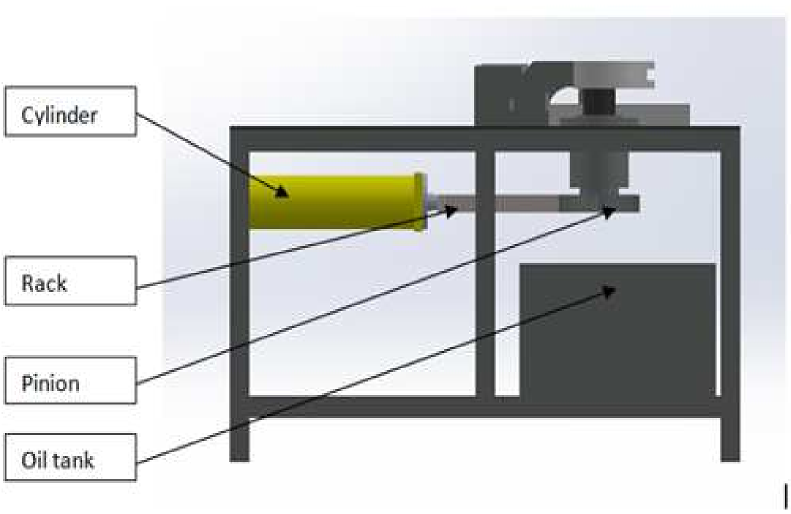


Figure 5: Sectional View of Rotary Pipe Bending Machine.

1.3.4. Mechanism of Bending In Rotary Bending Machine

Figure 5 shows the various parts of rotary tube bending machine. Here, the bending takes place by rotary action of the rotary table. The rotary table is firmly fixed to the rotor the locking action of the slot made in it. The rotor is operated by a pinion attached to it. The pinion is rotated by rack in mesh with it. When the gear lever is operated the oil is pumped into cylinder from the oil tank with an oil pump, which generates pressure inside the cylinder pushing the piston outside. The piston is in conjugation with the rack. Hence, the rack moves forward rotating the pinion, and hence the rotary table rotates bending the tube into the bending die. The pressure exerting in the process is displayed in a pressure gauge connected to the equipment. The amount of peak pressure acting can be varied by an adjusting a pressure screw which is provided. Generally, the pressure used for thin tube is lesser and for bending thicker tube, an adjustment must be made to increase the peak load required. Figure 5 shows the sectional front view of rotary pipe bending machine.

2. METHODOLOGY

The methodology consists of the following steps as shown in Figure 6

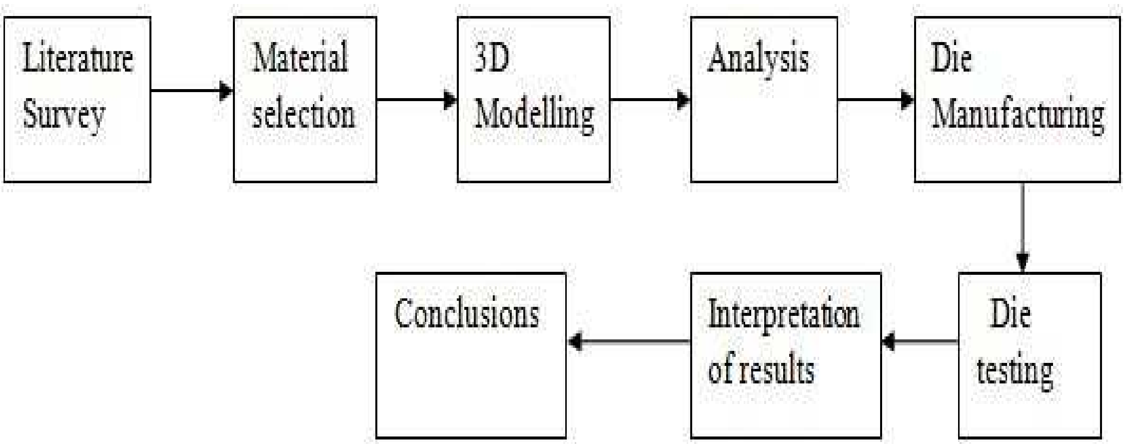


Figure 6: Steps involved in carrying out this work.

3. LITERATURE REVIEW

Tube bending process is one of the commonly used processes used in industries. The tube bending processes are modified according to the application. Frequent changes are made in either the process, method of bending or specifications of the tube used for bending according to the desired output. From the literature survey, the various works which took place in this area are discussed below.

ZHAO Gang-yao et al., [1] conducted experiments on distortion in cross section of the tube during bending process. The study was conducted by development of a finite element model on ABAQUS and its reliability was validated by experimentation. The tube material used is thin walled rectangular 3A21 Aluminium. The pipe was modeled using 4 node shell elements. The results show that maximum distortion occurs at the zone of maximum circumferential stress. The plane of maximum distortion is about 50 degrees with respect to reference plane, and its position was irrespective to the change in clearance provided between pipe tube and die. V. Nachimuthu et al., [2] conducted experiment on heat treatment of EN 8 steels and the variation in their properties. The microstructure of the steel was also observed after heat treatment. N. C. Tang [3] has developed a mathematical model, which gives details about stresses in the tubes, variation in wall thickness, shrinking rate at the tube section, deviation of neutral axis, preparation length of the bend, bending moment and flattening.

E. Daxin et al., [4] developed analytical model to study the stress distribution and wall thinning in rotary draw bending, based on ideal rigid-plastic material model. Here, elastic deformation and strain hardening are considered. Plane strain state is assumed. The deformation of the material assumes the condition of incompressibility. Equation for determining the axial force and contact force were also developed. The trend of variation in bending stress and wall, thickness is also discussed. F. F Song et al., [5] studied the behavior of high strength titanium tube bending under multi-die constraints. Using plasticity model a finite element model was developed to study the spring back behavior. It was found that both angular and cross-sectional spring back decrease with decrease in bend radius. Finally, a two stage spring back methodology is proposed to get the precision bending.

From the literature survey, it is evident that very few people have worked on analysis of pipe bending and to improve the process. And, no work is evident on design and fabrication of die for a square tube, and hence this work is undertaken to design and fabricate the die for square tubes.

4. MATERIAL SELECTION

Tube bending dies are subjected to heavy loads, shock loads and constant wear. Hence, the material selected should be able to withstand heavy impacts and wear due to constant rubbing action. So, generally materials like Hard Chrome Steels, Aluminum-Bronze, Alloy steels are used.

Table 2: Chemical Composition of EN 8

Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050 Max
Phosphorus	0.050 Max
Chromium	-
Molybdenum	-
Nickel	-

Table 3: Physical Properties of EN 8

Max Stress	700-850 n/mm^2
Yield Stress	465 n/mm^2 Min
0.2% Proof Stress	450 n/mm^2 Min
Elongation	16% Min
Impact KCV	28 Joules Min
Hardness	201-255 Brinell

In this work, as a compromise between cost and durability of the die, we used EN 8 which satisfies the requirements. Table 2 gives the details of chemical composition of EN 8 and table 3 gives the details of physical properties of EN 8. The properties obtained by chemical composition act as a basic material and the properties of the material can be further modified by various heat treatment processes.

5. MANUFACTURING OF DIE COMPONENTS

5.1. Manufacture of Bending Die

The raw material in the shaped of circular disc is mounted on lathe and turned to required dimensions. Later, a circular slot is made to accommodate the pipe bend. Figure 7(a) and 7(b) show the raw materials (EN8) used in manufacturing of die components. Figure 8 shows the final bending die produced after machining.

5.2. Manufacture of Support Bar and Pressure Dies

The billets were mounted on horizontal milling machine and made to required dimensions. Slots are made to aid the pipe bends. Figure 9 shows the pressure die and figure 10 shows the support bar produced after machining.

Figure 7(a): EN8 Billet used for Bending Die.

Figure 7(b): EN 8 Billets used for Support Bar and Pressure Die.

Figure 8: Bending Die.

Figure 9: Pressure Die.

Figure 10: Support Bar.

Figure 11: Bent Pipe.

6. HEAT TREATMENT

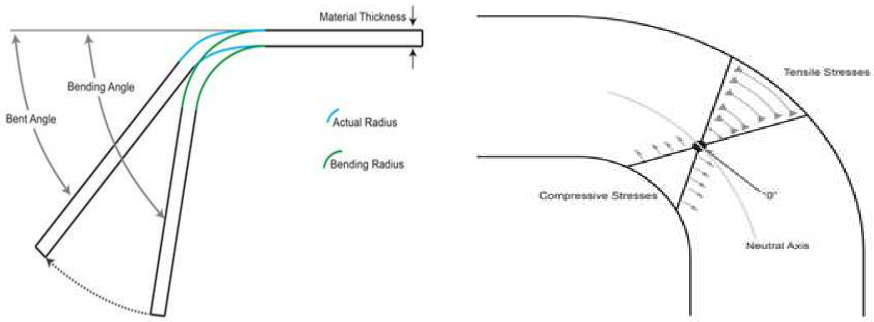
Heat treatment is a method of heating and cooling the metals to change their physical and mechanical properties, without letting it change its shape. Heat treatment can not only be used for strengthening materials, but could also be used to alter some mechanical properties such as improving formability, machining, etc. The specimens after machining are normalized by heating to a temperature of 830-860 degrees Celsius and then cooled in air. The brittleness induced in the specimens due to normalization is removed by tempering process, by heating them in a furnace to a temperature of 550-600 degrees Celsius for 4 hours. Finally, the specimens are quenched in water to get the hardened steel. Figure 12(a) and 12(b) shows the heat treatment equipment used in this work.

(a) **(b)**

Furnace used to Heat the Specimens **Quenching Tub**

Figure 12: Heat Treatment Equipment.

7. EXPERIMENTATION AND RESULTS



(a) **(b)**

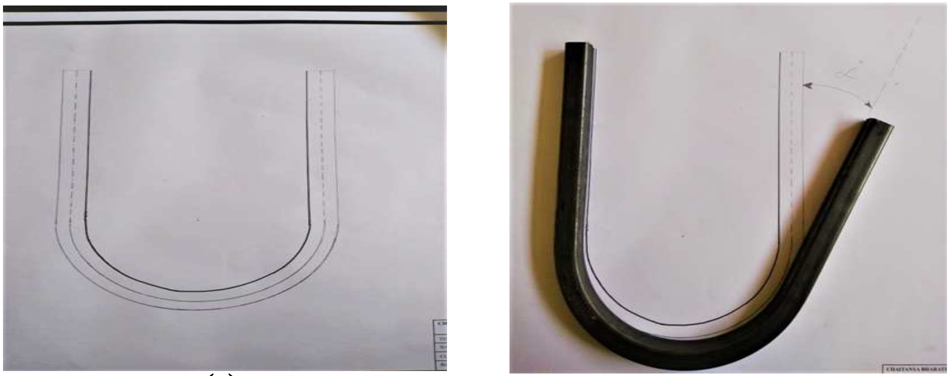
U-Bend Chart **Spring Back Measurement**

Figure 13: Phenomena of Spring Back in Pipe Bends.

The manufactured components are mounted and assembled on the bending machine. The attempt to bend the square tube was successful. The bending operation was carried out for tubes of different thicknesses, and the load acting in the process was recorded. The amount of spring back for each case is also tabulated.

7.1 Spring Back

The capacity or tendency of a bent or shaped elastic material (such as a metal) to revert to its original form is called as spring back. Figure 13(a) shows the phenomena of spring back and figure 13(b) shows the stress distribution in the tube after bending. Figure14 shows the arrangement made for spring back measurement.



(a) **(b)**

U-Bend Chart **Spring Back Measurement being carried out**

Figure 14: Provision for Spring Back Measurement.

Table 4: Variation of Spring Back With Bend Angles for Various Thickness (T) of Mild Steel Tubes (Pipes)

S. No.	Bead Angle (in degrees)	Value Of Spring Back (degrees)		
		T=1.2mm	T=1.5mm	T=1.8mm
1	30	7.5	6	4
2	60	9	9	8
3	90	13	12	11
4	120	16	15	14
5	150	19.5	18	16
6	180	23	21	19

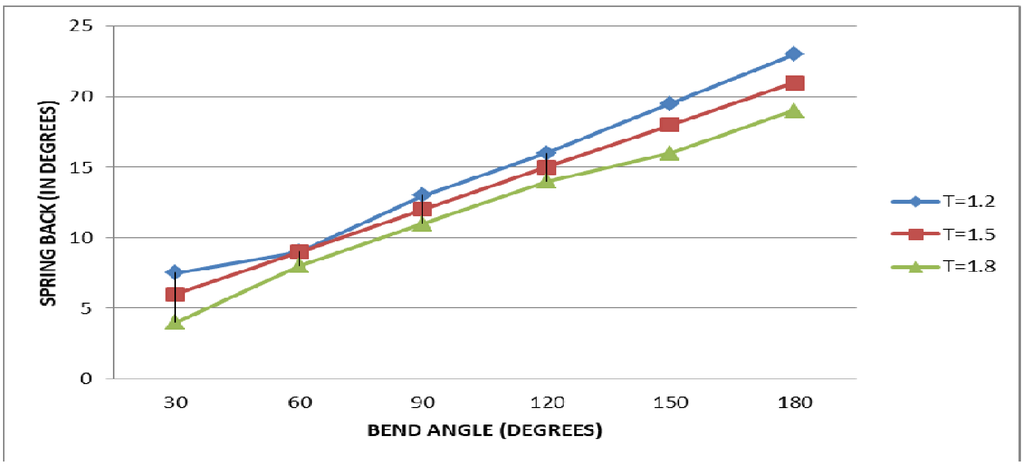


Figure 15: Variation of Spring back with various Bend Angles for different Thicknesses of Pipes (T) in mm.

Figure 16: Tube Bend without any Fillings.

Figure 17: Tube Filled With Plastic Granules.

Figure 18: Tube Bend with Sand Fillings.

Figure 19: Tube without Wrinkles after Bending.

Table 4 gives the variation of spring back (in degrees) with different thicknesses of pipes for different bend angles. The graph in figure 19 depicts that spring back increases with increase in bend angle, and spring back decrease with increase in tube thickness.

6.2 Pipe Bending With Fillings

Pipe bending was performed using different filling materials, to reduce wrinkling effect. Materials like sand, moulding sand and plastic granules were filled in the tube and sealed before bending it. And a reduction in wrinkling has been observed. Also, wrinkling has totally diappeared when the tube thickness is increased from 1.2mm to 1.8mm. Figure 16 shows a pipe bend without any fillings and wrinkling is observed. Figure 17 shows the pipe bend with fillings, where wrinkiling effect is lesser. It is observed that wrinkling effect gradually decreases with increase in pipe thickness, and totally disappeared as the thicknessof tube increased from 1.2 to 1.8mm. Figure 19 shows a bent square tube of 1.8mm thickness, which is free from wrinkles.

7. CONCLUSIONS

- The bending die along with two pressure dies and a support bar are manufactured**.**
- Tubes of different thicknesses were able to bend successfully with help of the bending die made.
- The bending die, pressure dies and support bar for tube bending is designed and manufactured according to the procedure described.
- The components manufactured are according to the design and are manufactured to closer tolerances.
- Spring back characteristics of mild steel tube of different thicknesses were studied. It is found that as thickness of pipes increased, the spring back decreased.

- Wrinkling reduced substantially when tube bending is performed using filling materials like sand and plastic granules.
- Bend pipes free from wrinkles are freely obtained, as the pipe thickness increased from 1.2mm to 1.8 mm.

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